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# IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE TO ENHANCE THE OVERALL EQUIPMENT EFFECTIVENESS IN MEDIUM SCALE INDUSTRIES

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***ABSTRACT***

***In current globe state, manufacturing companies are in need of sustaining their production level to meet the customer demand. Whenever capacity problem arises, immediately they look for increasing overtime, number of shifts and purchase new machines and equipments. As an alternative, they should focus on the better utilization of resources and increasing performance of the existing machines which leads to an improvement in the equipment performance, reduction in bottlenecks, decrease overall downtime, improve operator performance and minimize setup time and other major forms of losses, thus enabling in decision on the investment of buying new machines. In this research, an attempt was made to implement total productive maintenance to achieve overall equipment effectiveness (OEE) close to world class standards. Result analysis shows that, downtime losses are not the only influencing parameter, but idle time of a machine is another factor that adds to the variation in OEE. It is evident that the percentage OEE can be improved substantially by implementing total productive maintenance lean tools such as Jishu Hozen, Kaizen etc in a manufacturing company. While calculating OEE, the factors influencing it are identified and performance improvement measures are undertaken. From the observed results, it was found that, the percentage OEE can be improved from 55.45% to 68.04% by implementing this technique in medium scale industries.***

***KEYWORDS: Lean, TPM, OEE, Kaizen & Production Rate***

Original Article

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## INTRODUCTION

In present business scenario, every manufacturing company faces increasing competition and hence attempts to be an effective, low-cost producer of their product with high productivity. Many times, attaining higher productivity and bringing their product to the market with minimum cost is not possible due to various factors related to capacity problems and problems related to performance of machines such as machine breakdown, minor stoppages, unplanned maintenance, reduced speeds, quality rejects and rework. In such situation, an investment is made on buying new equipment, increased shifts and increased working hours. This causes business executives to be sensitive about all aspects of manufacturing operational costs. Hence lean tools must be used, as lean entails using less or the minimum of everything required to produce a product or perform a service. Overall equipment effectiveness measures the gap between the actual performance and the potential performance of a manufacturing unit. OEE encompasses three measuring metrics such as availability, performance and quality. These help gauge the plant's efficiency by categorizing the key losses that affects the manufacturing process. Downtime reductions can be readily achieved by using OEE to gain visibility into machine status and to perform root-cause analysis of problems.

## LITERATURE REVIEW

The total productive maintenance (TPM) idea presents quantitative metric OEE for measuring the equipment effectiveness in manufacturing line. It is an outstanding technique developed from the idea of preventive maintenance for manufacturing plant maintenance and management. Enhancement in production effectiveness is important factor in a process industry. Several researches were explored the problems associated with an injection molding process in an automobile parts manufacturing company. The problems such as breakdown of machine, production adjustments, poor working of defective equipments were identified and this lead to major losses in the company's growth. To overcome these problems TPM tools such as 5S, Jishu Hozen, Kaizen, and classification of abnormalities were implemented [1-5]. Improvement of OEE in a plastic injection molding industry has been measured to know the present situation of the plastic industry. Five bottleneck machines have been identified and present OEE has been calculated of availability of plastic industry denotes how effectively the machine is operating. Ability of workers and machines can be given by performance efficiency. Quality rate gives how efficiently the machine is utilized [6-9]. The OEE was developed with low machine breakdown, less idling and minor stop time, less quality defects, reduced accident in plants, increased productivity rate, optimized process parameters, worker involvement, improved profits through cost saving method, increased customer satisfaction and increased sales with enhanced worker self-confidence [10-13]. TPM is one of the world class manufacturing tools that seek to manage assets by involving everyone in the manufacturing organization. The financial and productivity benefits of implementing TPM are significant [14-17]. Many approaches have been proposed regarding TPM implementation procedures, of which logically sequenced implementation procedure is an identified success factor, yet the majority of TPM implementation attempts fail to achieve their intended goals [18-21]. TPM lean tool seeks to maximize equipment effectiveness throughout the lifetime of the equipment. It strives to maintain the equipment in optimum condition in order to prevent unexpected breakdown, speed losses, and quality defects occurring from process activities [22-25]. The integration of lean and green practices within parts production in the automotive industry, ultimately achieving an important reduction in production costs [26-30]. OEE is regarded as an important measurement for assessing the performance of equipment. The method distinguishes the six big loss types and three key performance measurements such as availability, performance rate and quality rate that combine into one consolidated metric [31-34]. Based on the above study the OEE was used in PVC pipe manufacturing industry of Vijay aqua pipes, Chennai to improve the performance of machinery and associated processes by identifying those performance opportunities that will have the greatest impact to the bottom line. Improvements in changeovers, quality, machine reliability, working through breaks and more can be measured and improved, utilizing the OEE metric.

## OBJECTIVES AND METHODOLOGY

The main objective is to improve the overall equipment effectiveness and implementation of autonomous maintenance in a medium scale PVC pipe manufacturing industry. The increase in efficiency and productivity of machines in terms of OEE are obtained from the autonomous maintenance by TPM approaches like to maximize overall equipment effectiveness, increase the operator involvement and improving the quality. The OEE in PVC pipe manufacturing industry can be improved by the methodology and the various steps involved are shown in figure 1.

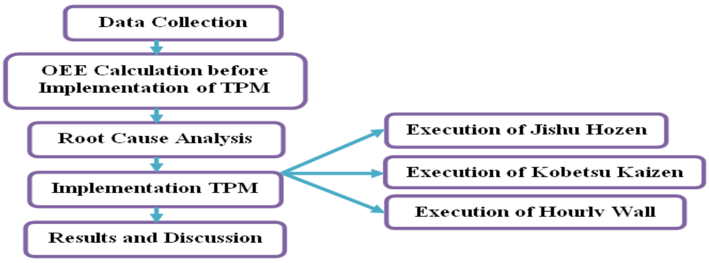


**Figure 1: Methodology Flow Chart**

**Six Big Losses**

OEE is a simple tool that will help to measure the effectiveness of their equipment. It takes most common and important sources of productivity loss, which are called six big losses given in the following Table1.

**Table 1: Six Big Losses**

| Sl. No. | Major Event Loss | OEE Metric | Loss Category | Example of Loss Category |
|---|---|---|---|---|
| 1 | Machine Breakdowns | Availability | Down Time | Equipment failures, Tooling damage, Unplanned maintenance |
| 2 | Machine Adjustments / Setups | Availability | Down Time | Process warm-up, Machine change over's, Material Storage |
| 3 | Machine Stops | Performance | Speed | Product misdeeds, Component jam, Product flow Stoppage |
| 4 | Machine Reduced Speeds | Performance | Speed | Level of machine operator training, Equipment age, Tool wear |
| 5 | Machine Bad Parts | Quality | Quality | Tolerance adjustment, Warm up Process, Damage |
| 6 | Machine Production Bad Parts | Quality | Quality | Assembled incorrectly, Rejects, Rework |

**Availability**

Availability is the ratio of time needed for operating the equipment to the time actually consumed for operation.

$$\text{Availability} = \frac{\text{Scheduled running time} - \text{Unplanned Stoppages}}{\text{Scheduled running time}} \text{X}100$$

Where,

Actual Running Time = Scheduled running time - Unplanned stoppages.

Unplanned stoppage means the period during which the line is stopped due to equipment failure, setup, adjustment and change over.

**Performance Rate**

The performance rate is the ratio between actual average production and standard production. This factor indicates the ratio of the actual output and the targeted output. Actual output is the actual performance of the operation and is less than the targeted output due to rough running of the equipment, jams and equipment wear.

$$\text{Performance rate} = \frac{\text{Actual Average Production}}{\text{Standard Production}} \text{X}100$$

Actual average production= $\frac{\text{Total production in a cycle period}}{\text{No.of working days in a cycle period}}$

### Quality Rate

This is percentage of good parts out of total produced sometimes called 'yield'. Quality losses refer to the situation when the line is producing, but there are quality losses due to in progress production and warm up rejects.

Quality rate= $\frac{\text{No.of products processed} - \text{No.of products rejected}}{\text{No.of products processed}} X100$

### Data Collection and Analysis

Company focuses on adaptability to different agricultural practices in the most efficient way. The company has earned accolades in manufacturing and providing drip irrigation systems, mist irrigation systems and PVC pipes. PVC pipes are also used for water harvesting. Ultimate customer satisfaction is our ultimate priority. Our products help conserve water by curtailing evaporation and enhancing deep percolation and thereby increasing the crop production. Company offers turnkey concepts of manufacture, design and installation to meet the irrigation needs of the customer for every type of crop. The existing OEE was calculated by collecting the data before implementation of TPM. The data was collected for sample of monthly production of PVC pipes during October 2017 to December 2017 and given in Table 2. The available time was found out for three months and given in Table3.

**Table 2: Monthly Production Rate During October to December 2017**

| Month | Production (Quintal) | Rejection (Quintal) |
|---|---|---|
| October | 1700.55 | 152.13 |
| November | 1575.72 | 125.07 |
| December | 1270.05 | 106.72 |

**Table 3: Available Time**

| | | |
|---|---|---|
| Shift 1 | 8.30 am to 8.30 pm (12hrs) | |
| Shift 2 | 8.30 pm to 8.30 am (12hrs) | |
| Total working hours | 24 hours 1440 mins | |
| Unplanned stoppages per day | 230 mins | |
| Scheduled running time for 3 month | Oct 24<br>Nov 26<br>Dec 25 | Total=75days<br>=108000 mins |
| Unplanned stoppages for 3 months | 17250 mins | |

Total pipe manufactured in three months is 4546.32 quintal, number of working days in three months is 75 days and standard production rate is 84 quintal per day. Output for three months 4546.32 quintal and rejection for three months is 383.92 quintal. From the date the availability, performance rate and quality rate were calculated.

Availability = $\frac{\text{Scheduled running time} - \text{unplanned stoppages}}{\text{Scheduled running time}} X100$

Availability= $\frac{108000-17250}{108000} X100$=84.03%

Actual average production= $\frac{\text{Total production in a cycle period}}{\text{No.of working days in a cycle period}}$

Actual average production = $\frac{4546.32}{75} = 60.62$ Quintal per Day

$$\text{Performance rate} = \frac{\text{Actual average production}}{\text{Standadr production}} \text{X100}$$

$$\text{Performance rate} = \frac{60.62}{84} \text{X100} = 72.16\%$$

$$\text{Quality rate} = \frac{\text{No.of products processed} - \text{No.of products rejected}}{\text{No.of products processed}} \text{X100}$$

$$\text{Quality rate} = \frac{4546.32 - 383.92}{4546.32} \text{X100} = 91.56\%$$

Hence, the current OEE of the machine was calculated as follows.

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality} \times 100$$

$$\text{OEE} = 0.84 \times 0.721 \times 0.915 \times 100 = 55.45\%$$

**Comparison of Existing Machine OEE with World Class Score**

World class OEE is a standard which is used to compare the OEE of the plant. The percentage of world class level OEE in worldwide studies indicates that the average OEE rate in manufacturing plants is 60%, but world class OEE is considered to be 85% or better. Clearly, there is a room for improvement of OEE in many manufacturing plants. The current OEE of the company is compared with world class OEE level and the results are shown in figure 2. From the details the result derive that there is scope to improve the OEE

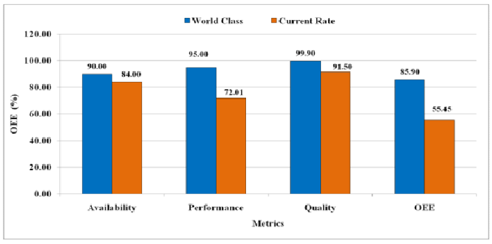


**Figure 2: Comparison of Current OEE with World Class OEE**

**Root Cause Analysis**

The following figure 3 shows the root cause analysis of the reduced OEE which will be discussed under the heading of man, machine, method and material. The causes of man, machine, method, material and environment will be taken an account for the analysis of the problem. From the cause and effect diagram, under the machine there are causes found out. They are spillage and improper maintained parts. Likewise under the man, lack of knowledge, operator awareness and also will be found out in method, there are reasons such as NO standard operating procedure (SOP) maintenance frequency also will be found out.

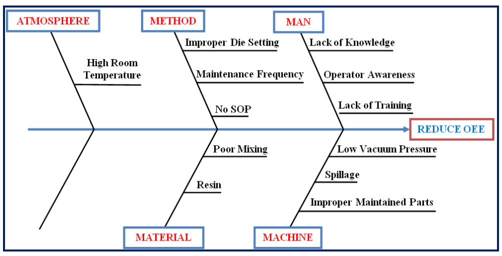


**Figure 3: Cause and Effect Diagram for Reduce OEE**

**Implementation of TPM**

The various pillars of TPM like Jishu Hozen, kaizen, planned maintenance and OEE have been implemented and also a maintenance plan has been prepared. Jishu Hozen also called autonomous maintenance is a team based approach to maintenance activities. The goal of autonomous maintenance is to prepare operators to do some equipment care independently of the maintenance staff. Jishu Hozen implementation lays the foundation for other maintenance activities by establishing the basic conditions for a machine operation. Various standards for cleaning, inspection and lubrication are set for estimated machine standards for cleaning and are given in Table 4.

**Table 4: Estimated Standards for Cleaning**

| Sl. No. | Location | Method of cleaning | Standard | Time | Frequency |
|---|---|---|---|---|---|
| 1 | Traction unit | Dry cloth | No dust | 3 mins | Daily |
| 2 | Vacuum tank (outer surface) | Dry cloth | No dust | 2 mins | Daily |
| 3 | Extruder (outer surface) | Pneumatic air cleaning | No dust | 4 mins | Daily |
| 4 | Printing unit | Dry cloth | No bur | 2 mins | Hourly once |
| 5 | Electric panel | Dry cloth | No dust | 2 mins | Daily |
| 6 | Electric motor | Dry cloth | No dust | 2 mins | Week |

After preparing the standards of cleaning procedure, the workers are asked to clean the operator table per shift due to dust and burr are removing and the workers feel the clean environmental. Similarly estimated standards for inspection are produced and given in Table 5. The inspection standards indicate the method of the time taken for inspection and the action taken if the process is not ok. The cooling tank water level, vacuum tank pressure, cooling tank inlet/outlet valve, vacuum tank inlet/outlet valve and self fitting machine will be observed frequently with their minimum and maximum level of standards. Similarly estimated standards for lubrication are produced and given in Table 6.

**Table 5: Estimated Standards for Inspection**

| Sl. No. | Location | Method of Inspection | Standard | Time (Secs) | Frequency | Action If Not OK |
|---|---|---|---|---|---|---|
| 1 | Cooling tank -Water level | Visual | Max & min | 20 | Shift wise | Fill water |
| 2 | Vacuum tank - Vacuum level | Visual | Max & min | 20 | Shift wise | Increase (or) Decrease |
| 3 | Cooling tank inlet/outlet valve | Visual | No leakage | 25 | Shift wise | Maintenance |
| 4 | Vacuum tank - inlet/outlet valve | Visual | No leakage | 25 | Shift wise | Maintenance |
| 5 | Self fitting temperature | Visual | $45^{o}C$ | 20 | Shift wise | Increase (or) Decrease |

**Table 6: Estimated Standards for Lubrication**

| Sl. No. | Location | Method of Lubrication | Type of Oil / Grease | Frequency |
|---|---|---|---|---|
| 1 | Vacuum tank trolley | Manual | Grease | Week |
| 2 | Traction roller | Manual | Grease | Week |
| 3 | Printing unit rack and pinion gear box | Manual | Grease | Week |

**Implementation of Kobetsu Kaizen**

A proper kaizen sheet is filled for each kaizen, which contains all information like before and after photographs, ideas and benefits. So, it any further other modification is suggested means this sheet is very helpful for that, some of the Kaizen's performed on machines are shown in the following figure 4.


**Figure 4: Kaizen Sheet**

The kaizen sheet explains the usage of screw driver for cleaning the mandrel leads to defect like line mark in mandrel. This defect in core mandrel will affect the quality of PVC pipe the kaizen were prepared to introduce the use to brass rod.

**Analysis and Implementation of Hourly Wall Thickness Checklist**

The defects occurring on pipe products are wall thickness variation, centering problems and diameter variation. In pipe products the following defects are frequently occurring defects, they are, uneven wall thickness and centering problems. From the data collected of our case study, diameter variation X -Chart analysis of 63 mm PVC pipe is developed for some samples in order to show clearly whether the production process is out of limit or control and is shown in figure 5.

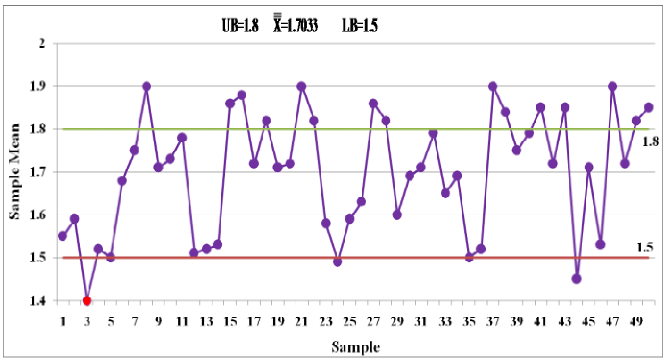


**Figure 5: X-Chart Analysis for Wall Thickness Variation**

The wall thickness of PVC pipe was periodically inspected and compared against the standards in an interval of one hour. This ensures the quality of the PVC pipe against any deviation in the wall thickness. If any deviation is found, then the operator will be instructed to adjust the thickness to the required control limit. Table 7 shows the checklist template which is prepared to note down the wall thickness for every hour. Similarly, hourly wall thickness checklist for PVC pipe after regulated to the specification limits after implementation and shown in figure 6.

**Table 7: Template for Hourly Wall Thickness Checklist**

| Operator | | | | | | | Date | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Machine | | | | | | | Shift | | | | | | |
| Time | OD min (63.11 To 63.16) | | W.T. (mm) 1.5 to 1.8 | | Weight (kg) 2.700 to 2.750 | | Time | OD min (63.11 To 63.16) | | W.T. (mm) 1.5 to 1.8 | | Weight (kg) 2.700 to 2.750 | |
| | OK | Not OK | OK | Not OK | OK | Not OK | | OK | Not OK | OK | Not OK | OK | Not OK |
| 8-9 | | | | | | | 2-3 | | | | | | |
| 9-10 | | | | | | | 3-4 | | | | | | |
| 10-11 | | | | | | | 4-5 | | | | | | |
| 11-12 | | | | | | | 5-6 | | | | | | |
| 12-1 | | | | | | | 6-7 | | | | | | |
| 1-2 | | | | | | | 7-8 | | | | | | |
| Inspected by: | | | | | | | | | | | | | |

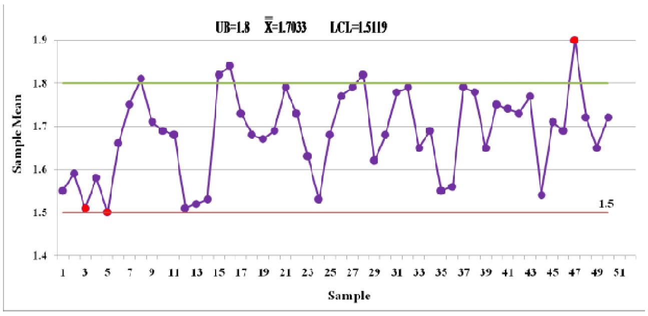


**Figure 6: Hourly Wall Thickness Checklists after Implementation**

## RESULTS AND DISCUSSIONS

The existing state of identified industry has very poor efficiency in terms of planned maintenance which is supported by the presence of very low OEE. The industry wide OEE is thus calibrated from the above details shows which is well below the global OEE level for process industries which stays around 85%. Thus, TPM implementation is needed to raise the current level of OEE nearer to the global average. As discussed above the TPM implementation is often a multi stepped process which seeks extensive control over the maintenance schedule autonomous maintenance. The OEE after implementation was calculated and shown in Table 8. The comparison of OEE before and after implementation of TPM in the industry is shown in the figure 7 which shows there is an improvement after implementation of TPM.

**Table 8: OEE Result after Implementation of TPM**

| | |
|---|---|
| Availability | 87.45% |
| Performance | 81.43% |
| Quality | 95.54% |
| OEE | 68.04% |

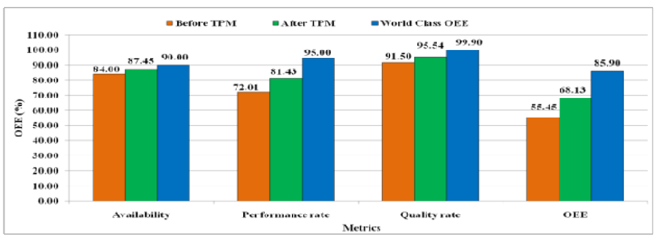


**Figure 7: Comparisons of OEE Results with World Class before and after TPM**

## CONCLUSIONS

In this research, we focused an implementation of TPM in a medium scale PVE pipe manufacturing industry. The existing OEE value was calculated and indentified the bottleneck to implement the TPM. From the observed results the following conclusions were made.

- From the previous records, before the implementation of TPM the OEE is 55.45% only.
- After successful implementation of TPM it was found that OEE is increased to 68.04%.
- Hence, the OEE has been increased about 13% by reducing the rejection rate and overall cycle time to meet the demand at right time.

The present work is focused to find out the root causes of machine related issues and to improve the performance levels of machines and their productivity through TPM methodology. It would be beneficial for future projects focused to improve the effectiveness of machines which have low OEE by implementing the TPM technique and setup time reduction by using different TPM metrics like MTBF, MTTR, etc.

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